Objective With At Least One Aspheric Lens

Cross References to Related Applications

Not applicable.

Statement Regarding Federally Sponsored Research or Development

Not applicable.

This Patent Application is a Continuation-In-Part of International Patent Application PCT/EP01/14314, with a priority date of 22 December 2000.

Background of the Invention

[0001] The invention relates to a lens with at least one aspheric lens surface, to an objective with at least one aspheric lens surface, and to a projection exposure device for microlithography and a method for the production of microstructured components with an objective having at least one aspheric lens surface.

[0002] Lenses with aspheric lens surfaces are increasingly used, particularly in projection objection objectives for microlithography, for improving imaging quality. For example, such projection objectives are known from German Patent Documents DE 198 18 444 A1, DE 199 42 281, US 5,990,926, US 4,948,328, and European Patent Document EP 332 201 B1.

[0003] Aspheric lenses are increasingly used in projection objection objectives for microlithography, for improving imaging quality. However, in order to attain the desired quality improvement by the use of lenses with aspheric lens surfaces, it is necessary that the actual shape of the aspheric lens surfaces does not deviate more than a

predetermined amount form the reference data of the lens surface. The permissible deviations between the reference surface and the actual surface are very small in microlithography, because of the finer and finer structures to be imaged. For testing whether a present aspheric lens surface corresponds to the required lens surface within the range of measurement accuracy, a special test optics is required. The quality of the aspheric lens surface is tested with this test optics.

[0004] The complexity of such test optics depends definitively on the surface shape of the aspheric lens surface. In particular, the use is desirable of aspheric lenses whose aspheric lens surface can be tested by test optics which can be provided at a justifiable cost and which preferably consists of a small number of spherical lenses.

[0005] It can also be necessary in the production of aspheric lens surfaces for the aspheric lens surface to have to be tested and reworked repeatedly during the production process.

[0006] Due to polishing also, an undesired and non-uniform change of the surface shape can arise in dependence on the surface because of polishing removal, resulting in an impermissible change in the aspheric lens surface.

[0007] Furthermore, it can also happen with aspheric lenses of high asphericity, that is, with a large deviation from a spherical surface, and with a strong variation of the local curvature, that these surfaces can be polished only with very small polishing tools, with a very large polishing cost, or it is nearly impossible to polish the aspheric surface. Just in the process of designing objectives, it is not comfortable if the designer can only find out, by multiple consultations with the polishing specialist and with the specialist responsible for preparing the test optics, whether a design he has developed can be

manufactured, or whether he has to change the design, so that a design exists which is also acceptable from manufacturing standpoints. Particularly when manufacture and development are spatially separated from one another, discussion and agreement between design and manufacturing entails a considerable cost in time.

Summary of the Invention

[0008] The invention has as its object to provide a method by which new designs with aspheric lens surfaces can be generated without consultation with manufacturing.

[0009] The object of the invention is attained by the following features:

By the measure of describing the aspheric lens surfaces by Zernike polynomials, it is possible to undertake a classification of aspheric lens surfaces such that the respective aspheric lens surface can be polished and tested at a justifiable cost when at least two of the three conditions (a)-(c) according to the following conditions are present:

$$P(h) = \frac{h^2}{R(1+\sqrt{1-\frac{h^2}{R^2}})} + K0 + K4 * Z4 + K9 * Z9 + K10 * Z16 + K25 * Z25$$
$$+ K36 * Z\ 36 + K49 * Z49 + K64 * Z64$$

with

Z4 = (2 x h2 -1)

Z9 = (6h4 – 6h2 + 1)

Z16 = (20h6 – 30h4 + 23h2 – 1)

Z25 = (70h8 – 140h6 + 90h4 – 20 h2 +1)

Z36 = (252h10 – 630h8 + 560h6 – 210h 4 + 30 h2 – 1)

Z49 = (924h12 – 27.72h 10 + h3150h8 – 1680h6 + h420h4 – 42h2 + 1)

$Z64 = (3432h14 - 12012h12 + 16632h110 - h11550h8 + 4200h6 - 756h4 +$

$56h2 - 1)$

where P is the sagitta as a function of the normed radial distance h from the optical axis 7:

$$h = \frac{\text{distance from the optical axis}}{\tfrac{1}{2}\,\text{(lens diameter of the aspheric)}} = \text{normed radius}$$

$$0 < h \leq 1$$

and wherein at least two of the following conditions is fulfilled:

(a) $\left| \frac{K16}{K9} \right| < 0.7$

(b) $\left| \frac{K25}{K9} \right| < 0.1$

(c) $\left| \frac{K36}{K9} \right| < 0.02$

the radius of the aspheric lens surface being fixed so that K4 = 0.

The object of the invention is also achieved when all of the above conditions (a through c) are fulfilled.

[0010] Thus it is possible for the designer, without consultation with manufacturing, to be able to make a statement about whether his design can be tested and produced.

The designer can limit himself to producing designs which can be tested and manufactured.

[0011] In particular, the presence of condition (c) has an advantageous effect on the manufacturability of aspheric lens surfaces.

By the measure that the proportions resulting from the Zernike polynomial, relative to the normal radius, do not exceed the following contributions, a class of aspheric lens surface is created which are outstanding for easy manufacturability and testability.

Those contributions are:

Zernike polynomial Z9,	$\leq$300 μm
Zernike polynomial Z16,	$\leq$ 35 μm
Zernike polynomial Z25,	$\leq$ 5 μm
Zernike polynomial Z36,	$\leq$ 1 μm
Zernike polynomial Z49,	$\leq$ 0.02 μm,

[0012] By analogy to a vibrating air column or vibrating string, the coefficients Z16, Z25, Z49, Z64, etc. could be described as the overtones of the aspheric object. The poorer in overtones, i.e., the faster the decay of the amplitudes of the components from the Zernike polynomials Z16 and greater, the easier it is to manufacture an aspheric. Furthermore, a compensation optics having lenses, or a computer-generated hologram, for testing the aspheric thereby becomes substantially insensitive as regards tolerances. In addition, rapid decay of the amplitudes makes it possible to find an isoplanatic compensation optics. The natural decay of the amplitudes of the Zernike contributions is decisive for the quality of matching of the test optics to the aspheric lens surface (residual RMS value of the wavefront). This is clear from the example put forward, with

a particularly harmonic decay of the higher Zernike amplitudes. It would also be undesirable to unnaturally decrease an individual higher Zernike term in its amplitude. A compensation optics of spherical lenses with a technically reasonable sin–i loading generates quite by itself a gently decaying amplitude pattern of higher Zernike terms.

[0013] It has furthermore been found to be advantageous to provide the aspheric lens surface on a convex lens surface. This has an advantageous effect on the polishing process.

[0014] It has been found to be advantageous to provide in an objective only aspheric lens surfaces which according to the characterization by Zernike polynomials are easily produced with the required accuracy.

[0015] It has been found to be advantageous, in order to further improve the effect of these aspheric lens surfaces, to arrange a spherical lens surface respectively neighboring the aspheric lens surface and having a radius which deviates at most by 30% from the radius of the aspheric lens surface. By this measure, a nearly equidistant air gap is formed between the aspheric lens surface and the adjacently arranged spherical lens surface. The designer is thereby freer in the curvature of the aspheric, which represents an additional important degree of freedom of the aspheric, without thereby making it difficult to manufacture the aspheric.

Brief Description of the Figures

[0016] Further advantageous measures are described in detail in further dependent claims using the embodiment examples.

[0017] Fig. 1 shows a projection exposure device;

[0018] Fig. 2 shows a lens arrangement of a projection objective, designed for the wavelength 351 nm;

[0019] Fig. 3 shows a lens arrangement of a projection objective, designed for the wavelength 193 nm; and

[0020] Fig. 4 shows a test arrangement for the aspheric lens used in Fig. 2.

Detailed Description of the Invention

[0021] The structure of a projection exposure device is first described in principle with reference to Fig. 1. The projection exposure device has an exposure device 3 and a projection objective 5. The projection objective 5 includes a lens arrangement 19 with an aperture diaphragm AP, an optical axis 7 being defined by the lens arrangement 19. A mask 9 is arranged between the exposure device 3 and projection objective 5, and is held in the beam path by a mask holder 11. Such masks 9 used in microlithography have a micrometer to nanometer structure which is imaged on an image plane 13 by means of the projection objective 5 with a reduction by a factor of up to 10, preferably a factor of 4. A substrate or a wafer 15 positioned by a substrate holder 17 is retained in the image plane 13. The minimum structures which can still be resolved depend on the wavelength λ of the light used for the exposure and also on the aperture of the projection objective 5; the maximum attainable resolution of the projection exposure device increases with decreasing wavelength of the exposure device 3 and with increasing aperture of the projection objective 5.

[0022] The lens arrangement 19 of a projection objective 5 for microlithography shown in Fig. 2 includes 31 lenses, which can be divided into six lens groups G1-G6. This lens arrangement is designed for the wavelength 351 nm.

[0023] The first lens group begins with a negative lens L1, followed by four positive lenses L2-L5. This first lens group has positive refractive power.

[0024] The second lens group G2 begins with a thick meniscus lens L6 of negative refractive power, with convex curvature toward the object. This negative lens is followed by two further negative lenses L7 and L8 . The lens L9 following these is a meniscus lens of positive refractive power, which has a convex lens surface on the object side and is thus curved toward the object. As the last lens of the second lens group, a meniscus lens of negative refractive power is provided, curved toward the image, and is aspherized on the convex lens surface arranged on the image side. A correction of image errors in the region between the image field zone and image field edge is in particular possible by means of this aspheric lens surface in the second lens group G2. In particular, the image errors of higher order, which become evident on observing sagittal sections, are corrected. Since these image errors, visible in sagittal section, are particularly difficult to correct, this is a particularly valuable contribution.

[0025] The aspheric lens surface is mathematically described by the following equation with the Zernike polynomials Z9, Z16, Z25, Z49 and Z64. For the aspheric lens surface, there holds:

$$P(h) = \frac{h^2}{R(1+\sqrt{1-\frac{h^2}{R^2}})} + K0 + K4 * Z4 + K9 * Z9 + K10 * Z16 + K25 * Z25$$

$$+ K36 * Z\,36 + K49 * Z49 + K64 * Z64$$

with:

$Z4 = (2 \text{ x } h^2 - 1)$

$Z9 = (6h^4 - 6h^2 + 1)$

$Z16 = (20h^6 - 30h^4 + 23h^2 - 1)$

$Z25 = (70h^8 - 140h^6 + 90h^4 - 20h^2 + 1)$

$Z36 = (252h^{10} - 630h^8 + 560h^6 - 210h^4 + 30 h^2 - 1)$

$Z49 = (924h^{12} - 27.72h^{10} + 3150h^8 - 1680h^6 + h420h^4 - 42h^2 + 1)$

$Z64 = (3432h^{14} - 12012h^{12} + 16632h^{10} - 11550h^8 + 4200h^6 - 756h^4 + 56h^2 - 1)$

where P is the sagitta as a function of the normed radial distance h from the optical axis 7:

$$h = \frac{\text{distance from the optical axis}}{\frac{1}{2}\text{ (lens diameter of the aspheric)}} = \text{normed radius}$$

$$0 < h \leq 1$$

[0026] The coefficients allocated to the Zernike polynomial and the radius are likewise given in the Tables, for describing the aspheric lens surface. The radius of the aspheric lens surface is fixed so that the following holds:

$$K4 * Z4 = 0 \quad \Rightarrow R$$

[0027] Other Zernike coefficients result with the selection of a differing radius. In particular, the Zernike polynomials of lower order would be changed. By selecting K_4 = 0 or nearly 0, statements about manufacturability and testability of the aspherics can be particularly easily derived from the Zernike coefficients. The component resulting from the Zernike polynomial Z9 contributes to spherical aberration of the third order. The portions resulting from the Zernike polynomial Z16 contribute to the correction of the fifth order spherical aberration. The contributions from the Zernike polynomial Z25 contribute to the correction of the seventh order spherical aberration, and the portions

from the Zernike polynomial Z36 contribute to the correction of the ninth order spherical aberration.

[0028] The third lens group G3 is formed by the following five lenses L11-L15. Two thick positive lenses are arranged in the middle of the third lens group; their surfaces facing toward each other are strongly curved. A very thin positive lens L13 is arranged between these two thick positive lenses, and has practically no refractive power. This lens is of little importance, so that this lens can be dispensed with if required, with slight modifications of the objective structure. This third lens group has positive refractive power.

[0029] The fourth lens group G4 is formed by three negative lenses L16-L18 and thus has negative refractive power.

[0030] The fifth lens group is formed by lenses L19-L27. The diaphragm is arranged after the first three positive lenses L19-L21. Two thick positive lenses are arranged after the diaphragm, and their mutually facing surfaces have a strong curvature. This arrangement of the lenses L22 and L23 has an advantageous effect on the spherical aberration. Account is taken by means of this arrangement of the lenses L22 and L23 of the principle of "lens of best shape", i.e., strongly curved surfaces are situated in a ray path of approximately parallel rays. At the same time, specific contributions to the undercorrection of the oblique spherical aberration are provided and, in combination with the two following meniscuses L24 and L25, which have an overcorrecting action on oblique spherical aberration, make possible an outstanding overall correction. The focal lengths of these lenses are f12 = 465.405 mm and f34 = 448.462 mm.

[0031] The sixth lens group G6 principally has a negative lens L28, followed by two thick lenses. Differing from the example described, it can be advantageous for reducing compaction to use quartz glass for the last two lenses of this lens group.

[0032] The length of this objective, from the object plane 0 to the image plane 0', is 1,000 mm. The image field is 8 x 26 mm. The numerical aperture of this objective is 0.75. A bandwidth of about 2.5 pm is permissible with this objective. The exact lens data can be gathered from Table 1.

Table 1

M1440a

Lens	Radius	Thickness	Glasses	½ Lens Diameter	Refractive index at 351 nm
0	Infinity	35.0240	L710	60.887	.999982
L 1	-908.93348	7.0000	FK5	61.083	1.506235
	284.32550	6.4165	L710	63.625	.999982
L 2	968.84099	23.7611	FK5	64.139	1.506235
	-212.21935	.7000	L710	66.550	.999982
L 3	413.73094	17.2081	FK5	69.428	1.506235
	-424.88479	18.8724	L710	69.711	.999982
L 4	591.81336	19.7102	FK5	69.490	1.506235
	-250.67222	.7000	L710	69.228	.999982
L 5	-2772.23751	12.8582	FK5	67.060	1.506235
	-255.60433	.7000	L710	66.381	.999982
L 6	4699.63023	9.0382	FK5	62.603	1.506235
	120.65688	26.0302	L710	56.905	.999982
L 7	-182.28783	6.0000	FK5	56.589	1.506235
	302.39827	20.1533	L710	57.318	.999982
L 8	-140.55154	6.0000	FK5	57.674	1.506235
	205.78996	.7000	L710	64.913	.999982
L 9	197.09815	10.0000	FK5	66.049	1.506235
	223.79756	27.0961	L710	68.261	.999982
L 10	-191.72586	8.0000	FK5	70.299	1.506235
	340.27531 A	2.2458	L710	77.287	.999982
L 11	-292.95078	19.3593	FK5	77.813	1.506235
	-143.32621	.7000	L710	80.683	.999982
L 12	1440.49435	47.0689	FK5	95.650	1.506235
	-155.30867	.7000	L710	98.253	.999982
L 13	-2647.76343	13.8320	FK5	100.272	1.506235
	-483.82832	.7000	L710	100.543	.999982
L 14	169.62760	45.9417	FK5	99.308	1.506235
	-1090.68864	3.2649	L710	96.950	.999982
L 15	102.07790	10.0000	FK5	77.455	1.505235
	100.38160	40.1873	L710	73.370	.999982
L 16	-504.79995	6.0000	FK5	71.843	1.506235
	130.61081	34.6867	L710	64.992	.999982
L 17	-153.51955	6.0000	FK5	64.734	1.506235
	284.44035	34.2788	L710	67.573	.999982
L 18	-114.12583	8.2925	FK5	68.531	1.506235

	731.33965	20.4412	L710	84.132	.999982
L 19	-291.19603	24.2439	FK5	86.387	1.506235
	-173.68634	.7000	L710	93.185	.999982
L 20	-10453.06716	28.2387	FK5	111.655	1.506235
	-304.21017	.7000	L710	114.315	.999982
L 21	-2954.65846	30.7877	FK5	122.647	1.506235
	-312.03660	7.0000	L710	124.667	.999982
Diaphragm	Infinity	.0000		131.182	.999982
	Diaphragm	.0000		131.182	
L 22	1325.30512	52.2352	FK5	133.384	1.506235
	-282.76663	.7000	L710	135.295	.999982
L 23	276.96510	52.6385	FK5	134.809	1.506235
	-1179.05517	25.2703	L710	132.935	.999982
L 24	-311.05526	10.0000	FK5	131.670	1.506235
	-587.25843	10.5026	L710	130.474	.999982
L 25	-374.19522	15.0000	FK5	130.116	1.506235
	-293.45628	.7000	L710	130.127	.999982
L 26	198.19004	29.6167	FK5	111.971	1.506235
	535.50347	.7000	L710	109.450	.999982
L 27	132.82366	34.0368	FK5	94.581	1.506235
	361.69797	12.8838	L710	90.620	.999982
L 28	7006.77771	9.7505	FK5	88.792	1.506235
	349.77435	1.0142	L710	79.218	.999982
L 29	174.38688	38.8434	FK5	73.443	1.506235
	55.37159	4.9107	L710	45.042	.999982
L 30	55.08813	42.8799	FK5	43.842	1.506235
	807.41351	1.9795	L710	30.725	.999982
	Infinity	3.0000	FK5	29.123	1.506235
	Infinity	12.0000		27.388	.999982

K4 = 0

K9 = 66445.43 nm

K16 = 33200.31 nm

K25 = 4553.78 nm

K36 = 843.85 nm

K49 = 172.24 nm

K64 = 30.49 nm

K0 = -37097.62 nm = offset

[0039] A lens arrangement is shown in Fig. 3, designed for the wavelength 193 nm and including 31 lenses. These 31 lenses can be divided into six lens groups G1-G6.

[0040] The first lens group includes the lenses L101-L105 and has positive refractive power overall.

[0041] The second lens group G2 includes the lenses L106-L110. This lens group has overall negative refractive power, and a waist is formed by this lens group. The first three lenses L106-L108 have negative refractive power, the lens L109 being a meniscus lens curved away from the reticle and having positive refractive power. The lens L110 is a meniscus lens curved toward the wafer and provided on the image-side lens surface with an aspheric AS1. A nearly equidistant air gap, which comprises a thickness of at least 10 mm, is formed by this aspheric lens surface AS1 and the following spherical lens surface S2 of the lens L111.

[0042] The lens L111 already belongs to the lens group L3, which includes the lenses of positive refractive power L111-L115. This lens group G3 has positive refractive power overall.

[0043] The fourth lens group G4 is formed by the lenses L116-L118 and has negative refractive power.

[0044] The fifth lens group is formed by the lenses L119-L127 and has positive refractive power. A diaphragm is arranged between the lenses L121 and L122. The sixth lens group G6 is formed by the lenses L128-L131, and has positive refractive power.

[0045] In the third lens group, the lens L111 is made of CaF_2. The use of CaF_2 at this point contributes to reducing the transverse chromatic error.

[0046] Furthermore, the positive lenses around the diaphragm, i.e., two positive lenses before the diaphragm and the two positive lenses L122 and L123 after the diaphragm, are made of CaF_2. Since the longitudinal chromatic error depends both on the ray diameter and also on the refractive power, the chromatic errors can be compensated well in the region of the diaphragm, since the ray diameter is greatest there and the refractive powers of the lenses are relatively high. In contrast to the CaF_2 lens L111 in the third lens group G3, these CaF_2 lenses L120-L123 have a certain amount of inhomogeneities, which can be compensated by a specific surface deformation on the respective lens. This is possible since only small variation of the ray inclinations occurs here.

[0047] A further CaF_2 lens L130 is provided in the last lens group L6. With this lens L130, a lens is concerned with a particularly strong radiation loading, so that the use of the material CaF_2 contributes to minimizing compaction and lens heating, since the material CaF_2 shows smaller compaction effects than does quartz glass.

[0048] With this objective, a very well corrected objective is concerned, in which the deviation from the ideal wavefront ≤ 7.5 mλ with $\lambda = 193$ nm. The distance between the object plane 0 and the image plane 0' is 1,000 mm and an image field of 8*26 mm^2 can be exposed. The numerical aperture is 0.76. The exact lens data can be gathered from Table 2.

Table 2

M1649a

Surface	Radius	Thickness	Glasses	Refractive Index 193.304nm	1/2 Free Diameter
0	Infinity	32.000000000	L710	0.99998200	54.410
1	Infinity	14.179159189	L710	0.99998200	60.478
2	-164.408664394	6.500000000	SiO_2	1.56028900	60.946
3	477.741339202	7.790005901	HE	0.99971200	66.970
4	2371.284181560	17.748516367	SiO_2	1.56028900	69.245
5	-223.822058173	0.700000000	HE	0.99971200	70.887
6	1195.174516496	16.908813880	SiO_2	1.56028900	75.329
7	-310.690220530	0.700000000	HE	0.99971200	76.162
8	485.562118998	17.669354706	SiO_2	1.56028900	78.088
9	-493.961769975	0.700000000	HE	0.99971200	78.165
10	283.324079929	21.403504698	SiO_2	1.56028900	76.391
11	-575.651259941	0.700000000	HE	0.99971200	76.178
12	219.789049573	25.467779640	SiO_2	1.56028900	70.691
13	103.024318785	22.996372410	HE	0.99971200	59.994
14	-1410.580832137	6.300000000	SiO_2	1.56028900	59.678
15	138.332121536	22.459549851	HE	0.99971200	58.321
16	-258.063359303	6.300000000	SiO_2	1.56028900	58.777
17	211.150408840	4.720624389	HE	0.99971200	63.072
18	285.055583047	10.000000000	SiO_2	1.56028900	64.494
19	341.327971403	25.082030664	HE	0.99971200	66.580
20	-155.970649922	8.215676832	SIO2	1.56028900	68.121
21	-340.915621 A	13.915549894	HE	0.99971200	76.026
22	-239.610088127	17.154283278	CAF2HL	1.50143600	81.795
23	-158.430656481	0.700000000	HE	0.99971200	85.540
24	2921.942532737	36.745821475	SIO2	1.56028900	100.629
25	-199.180375968	0.700000000	HE	0.99971200	102.642
26	581.258911671	38.708808511	SIO2	1.56028900	108.907
27	-317.375895135	0.700000000	HE	0.99971200	109.183
28	166.493530930	41.501871919	SIO2	1.56028900	100.340
29	Infinity	4.685571876	HE	0.99971200	97.519
30	189.438503324	15.000000000	SIO2	1.56028900	82.804
31	129.565379485	27.721937943	HE	0.99971200	72.481
32	-827.552674490	6.300000000	SIO2	1.56028900	71.203
33	193.630934593	25.802720751	HE	0.99971200	65.619
34	-188.509323766	6.300000000	SIO2	1.56028900	65.012
35	190.247434306	36.481919216	HE	0.99971200	65.037
36	-110.072588070	6.300000000	SIO2	1.56028900	65.743
37	827.067219258	19.846860784	HE	0.99971200	78.180
38	-240.277331422	13.511987588	SIO2	1.56028900	80.133
39	-184.012276263	0.700000000	HE	0.99971200	84.422
40	-8089.819259729	34.993850995	CAF2HL	1.50143600	98.673
41	-208.055465305	0.700000000	HE	0.99971200	102.289

42	1182.181885936	40.462877050	CAF2HL	1.50143600	113.699
43	-275.059004135	0.000000000	HE	0.99971200	115.480
44	Infinity	4.499000000	HE	0.99971200	115.366
45	1047.795255328	31.392914078	CAF2HL	1.50143600	117.911
46	-395.614261534	0.700000000	HE	0.99971200	117.992
47	284.811208676	40.095643635	CAF2HL	1.50143600	114.217
48	-822.040097050	25.559296680	HE	0.99971200	112.963
49	-230.468653441	12.000000000	SIO2	1.56028900	111.553
50	-1740.772555558	16.496567642	HE	0.99971200	112.486
51	-384.661514825	35.655800394	SIO2	1.56028900	112.495
52	-216.196472563	0.700000000	HE	0.99971200	114.658
53	166.072770698	31.752863257	SIO2	1.56028900	101.831
54	515.781794736	0.700000000	HE	0.99971200	99.354
55	136.216120952	28.320295414	SIO2	1.56028900	87.888
56	324.185504117	12.445936974	HE	0.99971200	83.547
57	2205.751425211	12.000000000	SIO2	1.56028900	80.947
58	315.974328907	0.700000000	HE	0.99971200	71.831
59	128.655046396	35.172368748	SIO2	1.56028900	65.168
60	57.302742004	1.258423244	HE	0.99971200	42.354
61	54.304405296	34.782435109	CAF2HL	1.50143600	41.547
62	328.213777698	3.191995120	HE	0.99971200	30.793
63	Infinity	3.000000000	SIO2	1.56028900	28.819
64	Infinity	12.000000000	L710	0.99998200	27.177
65					13.603

L710 is air at 950 mbar.

ASPHERIC CONSTANTS

Zernike component of the aspheric surface No. 21

ZER9 = 246.393 µm
ZER16 = 7.96520 µm
ZER25 = 1.39532 µm
ZER36 = 0.117584 µm
ZER49 = -0.0032066 m

relative to a half free diameter of 76.026 mm.

Aspheric coefficients:

K0 = -31597.65 nm
K4 = 0
K9 = 57834.73 nm
K16 = 29505.91 nm
K25 = 3835.77 nm
K36 = 655.93 nm
K49 = 133.64 nm
K64 = 23.24 nm

[0050] A possible construction of a test optics suitable for testing the optical properties of the aspheric lens surfaces contained in Figs. 2 and 3 is shown in Fig. 4. This test optics comprises 4 spherical lenses T1-T4 of quartz glass. The length of this test structure is 480 mm. The working distance, i.e., the distance between the last lens of the test optics and the aspheric lens surface to be tested, is 20 mm. A test object of up to a maximum diameter of 155.4 mm can be tested with this test optics. The input diameter of the test optics is 192.107. The maximum diameter of this test optics is 193.874 mm. The deviation from the ideal wavefront is 0.384 with a test wavelength of 632.8 nm. This residual error can be computer compensated.

[0051] This test optics is distinguished in that it is isoplanatic. The isoplanatic correction of the K-optics is valuable, since it contains the imaging scale with imaging of the aspheric lens surface from the middle to the edge on the interference image which arises. A constant lateral resolution is thereby obtained in testing aspherics. Because of the interference pattern which results on irradiation with a plane wavefront, the surface shape of the aspheric lens surface is determined by means of the interference pattern which appears.

[0052] The exact lens data of the test optics can be gathered from Table 3.

Table 3

Lens	Radius	Thickness	Material	Diameter	sin i
P1	1695.617	30.807	SIO2	192.11	0.057
	-263.187	34.771		191.75	0.555
P2	213.537	10.000	SIO2	161.68	0.172
	97.451	308.777		146.57	0.800
P3	154.172	36.663	SIO2	193.87	0.686
	595.848	45.306		190.04	0.043
P4	-246.667	13.677	SIO2	181.65	0.548
	-206.476	20.000		181.48	0.652

List of Reference Numerals

1	Projection exposure device
2	Illumination device
5	Projection objective
7	Optical axis
9	Mask
11	Mask holder
13	Image plane
15	wafer, substrate
17	Substrate holder
19	Lens arrangement
AP	Aperture diaphragm